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AN INTRODUCTION TO SOIL CONSERVATION
By A. L. Sharp
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It is my understanding that you are, for the most part, school teachers. At the risk of repeating an old saw which you may have heard many times, I might say that I welcome this opportunity to give you a bad time for an hour or so in retaliation for the many bad times school teachers have given me at one time or another in the past. Vengeance is not mine, however, so I appreciate this opportunity for an entirely different reason. That is that I am very much interested in this matter of soil conservation. I should be, I guess, because that's the way I earn my living, hope at least that I earn it.

I should like to begin this discussion with a definition of erosion. As some of you know better than I, the word erosion is a result of compounding the words "e," off and "rodo," gnaw. Erosion therefore literally means "gnaw off." Many agents cause erosion in two general ways: by movement of agents, and by agents remaining motionless. Running water, blowing winds, waves along coasts and glaciers are typical of the agents that erode by motion. Alternate freezing and thawing, or heating and cooling, the dissolving of limestone by carbonic acid and the freezing of water in rock crevices are examples of erosion by essentially motionless agents.

I should like, also, to point out that not all erosion is bad. The very soil that is the base of terrestrial life is itself a product of erosion. Our river valleys, our streams, our rolling hills, our mountains, are at least partially the result of erosion. Certainly the erosion that created these things was not bad, for us at least. This type of erosion is termed geologic erosion. It is a slow normal process which requires eons of time to do its work.

An entirely different type of erosion is so-called accelerated erosion - the process induced by a violent upset of the ecology of an area. Man himself is or has been responsible for most of this type of erosion, although lightening or volcanicly set fires probably caused some of it before man's advent on the earth. Almost all of this type of erosion is bad for us, the masters of all we survey, as we sometimes like to think of ourselves. This type of erosion can remove, or so shift about, the soils of an area rapidly enough to largely destroy its usefulness in less than a lifetime. Nor do we have to go to foreign countries to find examples of such land destruction. Just a few years ago, while on leave from the army during the war, I visited the little valley I lived in as a boy. The creek I used to swim in, play up and down, catch a lot of pan fish from, was at that later date a shallow stream meandering through a huge sand bed that, when I was a boy, was a fertile valley where corn grew so high I had to bend the stalks over to reach the ears. Most of the hills were in timber when I was a boy. They were later cleared and farmed. The sandy loam soil rapidly washed down into the valley where the sand stopped. The fertile part, the silts and clays, were carried on; leaving both the hills and the valley worn out or covered with sterile sand.

It may thus be seen that erosion is damaging to land in two ways, by removing fertile soil from one area and perhaps covering another fertile area with infertile material.

And this brings us to the subject assigned me for discussion, "An Introduction to Soil Conservation." Soil conservation is a broad term that is not easily defined. It means control of erosion like that I mentioned a moment ago, that removed the soil from the hills where I chased rabbits when I was a boy. It means prevention of deposition that destroyed the little valley where I grew up. It means draining the muck and bottom lands along our rivers so these lands may be put to more beneficial use. It means the watering of deserts so they will grow more produce. It means so controlling irrigation water and properly draining land that areas in irrigation projects will not become poisoned by alkali. It means so managing our lands that the wind will not blow them away. It means fire protection and control in our forests so that forest land will not wash away. Yes, and it might mean, if we could do so, the hastening of geologic erosion so that there will be more soil in such areas as basaltic scab lands. It can thus be seen that there is no simple definition of soil conservation. If there is one, it might be that "conservation of soil is using each bit of land for the purpose for which it is best suited, for the most good to the most of us for the longest time."

The definition must have the qualifying phrases, otherwise it might mean rapid soil destruction. For an individual corn farmer, in Iowa — I'll go far afield for an example, for certainly none of our farmers in this area would be guilty of such selfish motives — wanting to get rich quick, the best use for Joe Doakes in Iowa of his northwest 40 might be to grow corn every year. This could result, however, in virtual destruction to that NW-40. That would not be good for us, our children nor our children's children. We will need production from that 40 acres after Joe Doakes has made his fortune and moved to Southern California. And our children and their children in turn will need corn from that 40 acres. So, the definition for soil conservation must be qualified by adding those phrases "for the most good to the most of us for the longest time."

You, being teachers and a learned group, are no doubt familiar with the theory Thomas Robert Malthus propounded in 1798, that man's population tends to outstrip his food supply. The opening up of new continents, improved varieties of crops, improved techniques, technocracy, has tended to belie the Malthusian theory up to now. You are no doubt familiar, too, with the warnings of recent days in the - at least good - sellers, "Our Plundered Planet" and "Road to Survival" by Osborne and Vogt respectively, of the eminent approach of the fruition of the Malthusian Theory. Our own Benjamin Franklin and Thomas Jefferson had partial conceptions of what was occurring.

We must, of necessity, judge the future by the history of the past. Let us review a bit of history in order to see what erosion has done to our basic natural resource, our soil, and whether or not conservation of soil is important to us. I use the term, history, loosely here for some of it is legend, some arrived at by archeological findings and some by written records. The classic example of erosion is that of the near east, Mesopotamia, Palestine, Phonicia, Syria and Lebanon. At the beginning of the post glacial period, the Tigris and Euphrates rivers emptied into the Persian Gulf some 600 miles north of their present mouths. The period of continuous legend in this area began about 3,000 B. C. Since that time, the shoreline has moved south some 200 miles due to the filling of the gulf with erosional debris carried by the two rivers. Biblical Babylon was located in this area. It was a thriving prosperous area, with great irrigation, drainage and flood control works, an abundant agriculture. Much of it is now a desert of shifting sands, little but remnants left of early works of man. Palestine was once a land of milk and honey. Overgrazing of the hills and mountains and cutting of the trees caused accelerated erosion that left barren rocky hills and produced sterile debris which buried valley lands. Lebanon was the land of great

forests from which Solomon obtained cedar to build his temple. Lebanon is now largely barren due to erosion following the cutting of those forests and other continued misuse. Ancient Antioch was buried by 20 to 30 feet of erosional debris. During parts of this period of legend and ancient history parts of these lands were well tended, well preserved. Soil conservation was a general practice. It was even a part of the religion of the Hebrews and Babylonians. Wars and pestilences and other catastrophies, however, undid what these peoples accomplished and the nomadic or less careful peoples who supplanted them permitted erosion to proceed apace.

Modern Greece and, to a certain extent, Italy are now near destitution because of severe erosion which has virtually destroyed much of their soil resources from ancient to present times.

Herodotus, in the fifth century B. C., in writing of the Carthage area on the north coast of Africa said "the Cynips region yields three hundredfold," and that the Berenice area "brings forth in the best years a hundredfold." Again, wars, oppression, neglect, permitted erosion—this time largely wind erosion, to convert a prosperous agricultural area into one of shifting desert sands. Similar stories can be pieced out for Central Asia, parts of China, and other places anciently inhabited.

Here, closer at home, it is the considered opinion of the experts that erosion of the hills cleared for producing corn to feed the increasing Mayan population not only rendered the hills non-productive but filled the lakes, streams and valleys with sediment, destroying their usefulness, resulting in destruction of the Mayan civilization.

The surge of peoples of the world over this country in the late 18th and 19th centuries seeking opportunity, gold, religious freedom, political freedom, etc. touched off one of the greatest debacles in wastage of soil resources ever witnessed by mankind. The land was seemingly boundless in both productivity and amount. With a gun in one hand, an axe in the other, and flint and steel in his pouch, the pioneer surged westward, shooting, clearing, burning, plowing, "wearing out" the soil as he went. There were always new virgin farms just over the horizon to the west, and would always be, so why be concerned with a little erosion. When the old farm "wore out," a new one could be moved onto. Erosion was not even recognized as the primary cause of these lands wearing out!

The early warnings of Franklin and Jefferson went largely unheeded for 150 years by the nation at large. In a few localities in the cotton belt, where the problem of erosion literally forced attention of the land users by its very severity, the first feeble steps were taken to control erosion. These consisted principally of constructing a few Mangum Terraces, invented by a man of that name, in the late 19th century, in the cotton lands of the South. Elsewhere, and even there, erosion proceeded apace. We will never know, probably, the toll that erosion has exacted from us in wasted acres, lost plant nutrients, fertile land covered with sterile debris. Estimates, based on reconnaissance surveys, have been made of the progress of erosion in these United States of America.

We have 1,904,000,000 acres of land in the country. Slightly over half of this land, 1,054,000,000, is in farms and ranches. 381,000,000 acres are in public forests and private timber. There are 142,000,000 acres in public grazing lands, 55 million acres of Indian lands, 81 million acres in wild life refuges and parks, 24 million acres in roads, highways, and railroads, and 10 million acres in towns and cities. Of the slightly more than one billion acres in farms, just about

one-half, 500 million acres are in cultivation or can be cultivated. One-tenth of this land, 50,000,000 acres, has been essentially ruined by erosion, can no longer be farmer, probably won't be farmable for hundreds of years. Another ten percent has been severely damaged, is approaching final destruction. On another twenty percent, 100 million acres, we have lost half of the topsoil, and erosion has a good start on still another 100 million acres.

Let's recap. Of our crop land, we have ruined or severely damaged 20 percent, one hundred million acres. Half the topsoil has been lost from 20 percent more and still another 20 percent is being eroded. This leaves only 40 percent of our crop land with little or no damage. In addition, we graze about a billion acres of public and private forest and grass land. About half of this is eroding more or less rapidly.

It has been estimated that 2-1/2 acres of crop land is necessary to furnish each of us the food and fiber necessary to maintain our present standards of living. Our population is now about 145 million, and is increasing at a rate of some two million a year. Our present need of land, on this basis is about 360 million acres, and this is increasing at 5 million acres a year. Our rate of land loss, based on recent sample surveys, is 1/2 million acres a year.

We start as of now with 450 million acres, the original 500 million less 50 million already lost. Every year we lose another 1/2 million acres. Our needs are now 360 million but they increase 5 million acres a year. It does not take a good mathematician to see that, in the not too distant future, our annual losses and increased needs will soon use up that surplus of 90 million acres we have at the moment. According to my figures, it will occur about 16 years hence, or in 1965.

Under present conditions, then, we can expect, in less than 20 years to have only enough good land left to just feed us, with no exportable surpluses as we have always had heretofore. I used the term "under present conditions" advisedly. Any of a number of things could change this trend. Our birth rate could decline. Our death rate could increase. Improved varieties, techniques, etc. could increase unit production. We could make greater efforts to conserve our soil and reduce our losses. Chances are that a number of these things will occur. Probably, with the passing of war hysteria and flush times, our present high birth rate will decline somewhat. Indications are that death rates will not increase, may slow down more, in fact. Since we are a nation of tinkerers and researchers, chances are good that we will increase our unit production by improving crop varieties, mechanization, irrigation, drainage and pest and disease control. So, the picture is not as black as it appears at first glance. But more or less permanent loss of 1/2 million acres a year of farm land by erosion certainly is not complimentary of a nation such as this that leads the world in efficiency, production, living standards. This national rate of loss, if it were all concentrated in Oregon, would ruin all of the crop land in this state in about six years.

So much for what erosion is doing to us, costing us as a nation. But I might add here, before leaving the subject, that the story is much the same in most of the rest of the world, worse in parts of it, better in a little of it. Let us take a quick look at the erosion process, to see what and why and how it is. There are two agents that cause most of our erosion: water and wind. And there are three principle types or phases of erosion: sheet erosion, gullying and sand dunes. Sheet erosion, whether by water or wind, is the most dangerous type. It is insidious, like a thief in the night, stealing away our invaluable

topsoil particle by particle in thin layers or sheets, hence the term "sheet erosion." It may proceed for years without the land owner or operator being aware of it. First indications to him will be thin spots in his fields, patches that are low in productivity, drouthy, sandy, clayey. These are the spots where most of the topsoil is gone, leaving only the less fertile subsoil to be farmed. Sheet erosion may be caused by either or both wind and water. During wet weather rains churn up the soil and runoff carries it away. During dry weather, the wind lifts into the air and carries away the fine soil particles that give the soil its fertility.

Gully erosion may accompany or follow sheet erosion by water. And sand dunes may likewise accompany or follow sheet wind erosion. These types of erosion are plainly visible, like the highwayman who robs at gun point, not like the thief in the night that is sheet erosion. Although more spectacular than sheet erosion, gullying and drifting dunes, in general, are symptoms of much greater losses by advanced sheet erosion.

Now, what can be done about erosion? It is largely bare unprotected soils low in plant debris and organic matter content that suffer most losses from erosion. The basic principle in controlling erosion then is to so manage the soil and its vegetative cover that it will be bare the least possible amount of time, and to increase the soil binding organic matter. Supplementary control measures, such as contour tillage, terraces, gully check dams, hedge rows, etc., may also be needed in various combinations. And these combinations of treatments must be balanced against the hazards of the land. Some lands are so steep or otherwise hazardous that erosion simply cannot be controlled if the land is cultivated. These types of land must be in permanent cover of grass or trees if erosion is to be economically controlled. The term "economically" is used advisedly. Under our present economic condition, some of our land erosion cannot be controlled if in cultivation. Some day, in the very distant future I hope, our need for crop land may be so great that we may have to bench terrace some of these lands at enormous costs to control erosion so we can use them intensively, just as is now being done in land hungry parts of the world, such as parts of China, India, Java, Central Europe, etc.

I shall not go further into details on this matter of methods of controlling erosion. That is outside the scope of the subject assigned me. It was necessary, however, to mention the basic principles of erosion control, and having so done, I shall pass on to what is being done now in our country to conserve our soil.

As indicated earlier today, we were warned in colonial days by Franklin, Jefferson and others of what was happening to our greatest natural resource, our soils. But we did not heed those early warnings. We went along for over 100 years like a wastrel on a binge literally casting our soils into the wind and flood waters. And this kind of bread cast upon the waters is not returned to us at all, much less manyfold.

The first awakening of a conservation spirit in this country was indicated by establishment of our National Forests about the turn of the century. But not for another 30 years did we, as a nation, take our initial steps in conserving our soils. In 1929, just 20 years ago, Congress appropriated $160,000 for the Department of Agriculture to use in investigating erosion. Ten experiment stations were installed under this program in as many great soil regions in the next few years, in cooperation with several states. The Conservation Experiment Station at Pullman, Washington, in the Palouse soil region, is representative of the stations established.

Further impetus was given soil conservation with the passage of NRA in June 1933, which provided for, among other things, erosion control work as a means of unemployment relief. In September of the same year, Soil Erosion Service was established in the Department of the Interior as a temporary agency to carry out the NRA provisions for erosion control as an unemployment relief measure.

Dr. H. H. Bennett, who, for many years as a soil scientist with the Department of Agriculture, had been studying erosion and crusading for its control, was appointed director of Soil Erosion Service. During the next 18 months, the Service established demonstrations of erosion control on watersheds in most of the states of the union. Forty-one such demonstration areas were established, and in addition, about fifty Civilian Conservation Corps camps were under the supervision of the Service establishing farm erosion control demonstrations.

In March, 1935, Soil Erosion Service was transferred by presidential executive order to the Department of Agriculture, where it was combined with the erosion experiment stations, erosion nurseries and CCC camps previously assigned to the Forest Service for erosion control work.

In the meantime, several congressional committees were studying the national problem of erosion and framing a bill to express a national policy relative to soil conservation. The result was the passage, without a dissenting vote, in 1935, of the Soil Conservation Act. This was signed by the president April 27, 1935. It specifically established, in the Department of Agriculture, a Soil Conservation Service for the development and prosecution of a long-time program of soil and water conservation. The old Soil Erosion Service was absorbed by the new Soil Conservation Service.

In that year, 1935, many new, smaller demonstration watersheds were instituted, 150 more CCC camps originally assigned to Forest Service were reassigned to SCS, and about 300 new camps were opened. All of these, plus the old camps, stations and demonstration areas, were demonstrating practical methods of conserving our soils.

All of these activities were conducted in close cooperation with each of the states and most of the territories.

Early in this program, it was realized that the key figures in soil conservation were the nations' farmers and land owners. Without their initiative and active cooperation, soil conservation could not be attained without resorting to police state methods, which were abhorrent to we democratic people. And I don't mean a capital "D" in that democratic, not the Democratic Party, but a democratic, small "D", people. As a matter of fact, our national erosion control efforts were started under a Republican Administration, back in 1929 to 1932, with the establishment of the original erosion experiment stations.

But, to get back to the key figures in soil conservation, the farmers and land owners. How could they best take the lead in conserving our soils? What organization could best serve to implement a national policy of soil conservation and yet function on a local level? In the mid-30's, agricultural leaders in several states pressed their state legislatures for passage of enabling acts that would permit farmers and land owners to organize Soil Conservation Districts. The first of these acts were passed in March 1937 by Indiana, North Dakota, New Mexico, North Carolina and Nevada. Since then all of the remaining states and the territories of Hawaii, Puerto Rico, Virgin Islands and Alaska, have passed similar enabling acts.

These enabling acts permit groups of farmers and land owners to organize districts to undertake soil conservation cooperatively. These districts do not have taxing powers and can not force changes in land use, except under very special conditions, bordering on catastrophies. They are locally governed by boards of directors elected by popular votes, in most cases. In some states one or more board members are appointed by the states.

The Secretary of Agriculture directed that on and after July 1, 1937, new demonstrations and other federal aids in conserving our soil and water be undertaken only in cooperation with such legally constituted districts.

As of December 31, 1948, 2,094 Soil Conservation Districts had been organized in the 48 states and 4 territories. These districts contain a gross of one billion 147 million acres of land, 4 million 445 thousand farms and ranches and 3/4 billion acres of land in farms. It can thus be seen that a large percentage of our farmers are at least thinking about conservation enough to organize districts. In Oregon, there are now, for all practical purposes, 29 such districts comprising 5-1/2 million acres in 9,181 farms and ranches.

This part of the picture is bright. Catalogued land treatment, however, is lagging behind the organization of districts. I say "catalogued" because our records contain only those acres we know about and which are covered by cooperative agreements between the districts and the land owners and operators. There is actually a lot more acres being treated by individual farmers than for which we have records.

I might say here that the modus operandi of Soil Conservation Service is to cooperate with such districts at the request of the districts through arrangements covered by memoranda of understanding. The Service enters the picture only at the invitation of the districts. Most of the assistance it renders these districts consists of "know how," technical assistance, such as that of conservationists, soil surveyors, engineers, range specialists, foresters, whatever is needed to help the districts and farmers properly plan and execute soil and water conservation programs on their farms and ranches. We may also, depending on circumstances, furnish when available a limited amount of special equipment such as drag lines, bulldozers, terracers, and special farm tools required in conserving soils and water but not generally used by the farmers of the district. We sometimes also furnish limited amounts of seed of new grasses, legumes, etc., not on the market, for introductory purposes. These things are done for, or furnished to, the districts in accordance with written and signed cooperative agreements that spell out what the district and the Service will do. The districts, in turn, render aid to the farmers and ranchers in accordance with cooperative agreements that cite what each will do. All this is purely voluntary, in accord with our democratic principles. We, as a Service, exercise no control over either the districts or the cooperators within the districts. We make no payments to them. We simply supply what technical and other assistance we can, at the request of the districts and farmers.

This is true for both our regular activities and flood control activities. The Department of Agriculture is jointly responsible with the Department of the Army, Corps of Engineers, for flood control activities. The Corps has primary responsibility along the larger streams while Agriculture's primary responsibility is on the watershed lands and along minor tributaries. It is recognized that flood control problems are watershed problems, and this is the way Congress decided it should be attacked by the two departments.

The Department of Agriculture is conducting three flood control surveys in Oregon at the moment, in the Willamette, and over on Willow Creek near Heppner, and Walla Walla River, north of Pendleton. Most of the watersheds in the state are authorized for surveys, which will be completed as rapidly as funds and personnel will permit. When and if watershed flood control programs are authorized for installation, these works will probably be installed cooperatively with districts just as are regular soil and water conservation measures. At least, this is the plan being followed on two watersheds in California, and several back east.

But, to get back to land treatment to conserve our soils. As I said, treatment is lagging behind the formation of districts, and erosion, for that matter. Soil conservation measures have been planned for a total of about 175 million acres and a little less than 100 million acres have been treated. Only about one-third of this is crop land, the remainder being pasture, meadow and forest lands. We have made only a bare start, therefore, in conserving our soils. About two-thirds of our nearly two billion acres of land needs treatment of a preventative or curative nature. We have treated less than 100 million acres, one-thirteenth of it.

We are, in effect, in a race with time and erosion. At the moment it appears that we are losing that race, despite our best efforts so far. Perhaps, however, we should not be too discouraged. We have had a national policy of soil conservation now only about fifteen years, less than one-tenth of the time erosion has been occurring. In that time, much has been attained in awakening all of us to the hazards of erosion. Even many city people are now aware of the inroads erosion has made on our supply of good topsoil.

And it is very significant of the progress we have made that such a group as this should be interested enough in the subject of soil conservation to devote as much time to it as you are. It is only through a process of education that we can conserve our soils unless we resort to dictatorial methods, the police state. You, as teachers, being largely responsible for the education of our children and youth, have much to do with the kind of citizens we will have tomorrow. You have an opportunity to see that we do not have, in the future, a nation of Joe Doakeses, like that Iowa corn farmer, I mentioned earlier, but rather that we have a nation of farmers who will so use this land of ours that it will be for the good of the largest number of us for the longest time. And that we have a nation of city and towns people who understand and appreciate the fundamental necessity of preserving the productivity of our land.

And, it is a fundamental necessity to so do. I should like, in closing this discussion, to leave with you this thought, if no other. It is a matter of the utmost and urgent importance to each man, woman and child of us to conserve our soil and water resources lest civilization itself shall be washed down the ravaged slopes of the world to a barbarian existence in the debris of erosion.

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DETERMINATION OF FREQUENCY
OF RAINFALL AND RUNOFF

As indicated earlier today, many of the factors involved in precipitation are unrelated, hence the occurrence of rainfall has in it many elements of chance. And rates and amounts of runoff, involving precipitation with its unrelated factors, and still other unrelated factors, has even more elements of chance. These elements of pure chance in rainfall and runoff necessitates the use of statistics in the determination of the frequency of occurrence of both, the chances of any given amount or rate occurring.

It is not necessary to define for this group frequencies of occurrence. I would like, however, if at all possible, to dissociate in your minds the frequencies of rainfall and runoff. These are not synonomous. A given frequency of rainfall results in a less frequent runoff. A given frequency of runoff results from a more frequent rain -- frequencies stated in years between occurrences.

There are two general methods of stating frequencies: years and percent of time. The latter is the correct terminology. The former is somewhat misleading in that, to the novitiate, a ten-year frequency rain indicates that about every 10 years a rain of a given size will occur. This is not correct. A 10-year rain is a 10 percent occurrence, and means that in 10 percent of the years, a rain will occur that equals or exceeds a certain size. Supposedly, any average 100-year period will have 10 such rains. But they could conceivably occur in 10 consecutive years, with the remaining 90 years having no events equal to the

10 percent one. It is satisfactory to use years in expressing recurrence intervals if this is clearly understood. But care must be employed not to mislead those not so well versed in the terminology of frequencies.

Just to keep the record straight, recurrence interval in years is the reciprocal of percent of occurrence, and vice versa. A 2% rain is synonomous with a 50-year rain (100% ÷ 2% = 50 years). A 2-year rain is a 50% occurrence (100% ÷ 2-yr. = 50%). Incidentally, the 50% occurrence will be very nearly the arithmetic average of the array of events.

There are several methods of determining frequencies in use at the present time. And there are two general methods of assembling data. Both methods of assembling data, and the several methods of treating it, are equally applicable to rates or amounts of rainfall or runoff.

The proper method of assembling the data is determined by the requirements of the problem. If the frequency of occurrence of the greatest annual event is desired, then only the single greatest annual (or seasonal) event for each year of record is tabulated and studied. On the other hand, if it is desired to know how many times in a period of years events will equal or exceed a given amount, all events exceeding a selected minimum or base event are tabulated, regardless of how many times a year the events occur.

For instance, if it is desired to build a permanent check dam capable of discharging a 2% chance flow, then the greatest event for each year of record is used in the determination of probable

frequencies. On the other hand, if it is desired to design a sod spillway which must have a given average time interval between flows to recuperate, then all flows in the period of record must be tabulated and studied to determine the average number of times a year the spillway will be used for any given size of flow.

The design of a spillway and storage capacity of a flood control reservoir would probably be based on a study of the annual events, the theory being that if the structure has capacity for the largest annual event, a percentage occurrence event, it will have more than enough capacity for all the smaller events. A reservoir to conserve water, on the other hand, should be designed on the basis of the probable size and number of events to be expected. A farmer or rancher is probably more interested in the number and size of rains he can expect than in the greatest event he can expect. The engineer, on the other hand, faced with the necessity of designing hydraulic structures, and having no stream flow records, is more interested in the annual maximum events.

For part of this discussion, and the one to follow on correlation and regression, data from two streams in Oregon, Little Sandy River and Johnson Creek, will be used, not because they are applicable here, nor the best samples that one could find, but because the data was at hand, having been assembled for another purpose. The data appear in Table 1. For the discussion of treatment of numbers of occurrences, the data for Santa Ynez, California, used earlier today, will be used. This original material is not included herein because of its volume. Table 1 of the discussion of storm patterns is illustrative of

the data. It should be pointed out that this material is <u>not</u> indicative of the actual occurrences at Santa Ynez. Only a few of the records were used, just those in the 12-hour storms tabulated previously. The numbers of occurrences in the material, by classes, together with cumulative numbers equaling or exceeding any size class, and the number that may be expected a year, are shown in Table 2. The data in the last two columns were plotted as shown in Figures 1A and 1B. Had all of the rainfall record at Santa Ynez been utilized in this tabulation these two curves would be more or less representative of the hourly rainfall that could be expected at this station. Curve A would indicate the number of times any hourly amount could be expected to be equalled or exceeded, and curve B would indicate the number of times per year any given amount in one hour might be expected.

There are other methods of analyzing data of this type but they are too involved to present here, under these circumstances.

The above type of analysis is very useful for certain purposes. For instance, if it be assumed that total daily or storm rainfall of 0.3 inches (or some other figure) or less is largely ineffective for supplying moisture for crops due to losses by interception, evaporation, etc., this type of analysis is one of the best for indicating effective rainfall. It is also very useful in determining water yields of watershed, where stream flow records are available.

In ordinary frequency determinations, the annual-event method or partial-duration-series method may be used. In the former, only the greatest annual event is used, while in the

latter all events above an arbitrarily chosen base are used, regardless of the number of events a year. For those who wish to pursue this matter further, the following references are given:

Flood Flows, 1930, Allen Hazen, John Wiley and Sons, New York.

Theoretical Frequency Curves, 1924, H. A. Foster, Trans ASCE V. 87 pp. 142-203

Straight-Line Plotting of Skew-Frequency Data, 1927, R. D. Goodrich, Trans ASCE V. 91 pp. 1-91

New Curve-Fitting Method for Analysis of Flood Records, 1940, John C. Geyer, Trans AGU 1940 pp. 660-668

U.S.Geological Survey Water Supply - Paper 771, 1936

American Asymmetrical Probability Function, 1936, J. J. Slade,Jr., Trans ASCE V. 101 pp. 35-104

On the Plotting of Flood Discharges, 1943, E. J. Gumbel, Trans AGU 1943, pp. 699-716

Floods Estimated by Probability Method, 1945, E. J. Gumbel, Eng. News-Record V.134 p. 833

Simplified Plotting of Statistical Observations, 1945, E. J. Gumbel, Trans AGU, V. 26 Part I, pp. 69-82

A Simple Method of Estimating Flood Frequencies, 1943, Ralph W. Powell, Civil Engineering, Feb. 1943, pp. 105-6

Simplification of the Gumbel Method for Computing Probability Curves, 1949, W. D. Potter SCS-TP-78

Briefly, several of the methods are as follows:

No name $RI = \frac{N + 1}{n}$

where RI equals recurrence interval; N is the total number of items in the array, and n equals the position of each item in the array, with the largest event being number 1.

(The same nomenclature will be used throughout the following discussion).

The premise on which the above equation or formula is based is that for any number (N) of items in an annual series there are N + 1 intervals into which any subsequent event may fall which are the N - 1 items between the largest and smallest and two additional intervals, one above and one below the array. This formula is being currently used by U.S.G.S. and is coming into greater use by others.

$$\text{Hazen} \quad RI = \frac{N}{n-1/2}$$

This method has been widely used, by U.S.G.S., the Corps of Engineers, S.C.S. and others. Its use is decreasing, however. It assumes that an event of any given magnitude will occupy a medial position among events of the same relative rank in a large number of series.

$$\text{California Method} \quad RI = \frac{N}{n}$$

Not much in use now although formerly widely used. This method assumes that the events in the period of record will have the same frequency distribution as those of a longer period. In this method, the greatest event in the array would have a recurrence interval equal to the length of the record.

Gumbel - not reducible to a simple formula.

The Gumbel method, utilizing the modal (most common) event and the logarithmic rate of increase, arrives at a frequency distribution of events with coefficient of skew implied as a constant, 1.139. The two parameters, modal event and rate of logarithmic increase, are computed from the mean event and the standard deviation of the series. Potter's simplification is

recommended for use if this method is employed.

There are several other methods with which I am not very familiar. Among these are two variations of the Binomial theorem expansion, one recently adopted by the Bureau of Reclamation, and several involving corrections for skew.

The data in Table 1 will be used to illustrate the above methods. It might be well to add here, that any of the above methods are equally well adapted to treatment of annual events and partial-duration-series arrays. In the latter case, however, the result is simply the number of events that will equal or exceed a given size without relation to time, or frequency in years.

In Table 3 the peak annual discharges of Little Sandy river, taken from Table 1, for 30 years are arranged in descending order of magnitude. There is also shown in Table 3 the recurrence interval in years and percent (plotting positions) for the array of discharges, as determined by several methods. It will be noted that for the larger more rare events, there is little difference in recurrence interval except for the Hazen method, which is 60 years compared to 30 for the California method. 31 for $(N + 1)/n$ and 25 for Gumbel. There are also slight differences at the lower end of the array but these are relatively unimportant for most purposes.

These data are plotted on probability paper in Figure 2 and logarithmic paper in Figure 3. On probability paper there is little difference in any of the curves excepting that derived by Hazen's method, which gives lower rates for a given frequency

than the others, particularly for the more infrequent events. In Figure 3 it will be noted that the California method gives a radically different curve than the other three, and that the other three differ materially only for the more infrequent large events (curves were fitted by eye).

The choice of a method for use in determining probable frequencies at a given station is largely one of personal judgment, where the length of record is short, because there is no way of checking the accuracy of any method immediately. Only the passage of many years and the accumulation of additional records will prove the selected method right or wrong. From a statistical standpoint, probably the Gumbel method is the best. And if this thesis is accepted, the empirical methods which closely approach it should be acceptable. This would eliminate the Hazen and California methods, leaving that where recurrence interval equals $(N + 1)/n$ for our use, if we find the Gumbel method too laborious.

Incidentally, in all these methods excepting Gumbels, where the known largest event antedated the array at a known time, the plotting position of the known largest event is computed separately, its recurrence interval being determined in the same manner as the other events. For example, assume that the largest flow of Little Sandy, 5,000 c.f.s., occurred in 1910. The recurrence interval of that event would be:

$$RI = \frac{N+1}{n} = \frac{40+1}{1} = 41$$

$$RI = \frac{N}{n-1/2} = \frac{40}{1-1/2} = 80 \text{ (Hazen method)}$$

$$RI = \frac{N}{n} = \frac{40}{1} = 40 \text{ (California method)}$$

The big difficulty for us in this region in determining frequencies is that we do not have many records of sufficient length, of either rainfall or runoff. The treatment of shorter records, some of them, will be discussed in the next period.

Before going on to this, however, it might be well to further simplify Potter's simplification of Gumbel's method. For actual use, all that is needed is the material on pages 7 and 8 and the charts, Figures 13 and 14, pages 21 and 22. All the rest of the material is explanatory of Gumbel's method and the derivation of short cuts.

All that is needed, actually is the equation for coefficient of variation at the top of page 7, the table at the top of page 8 and the charts. The equation is:

$$C_v = \frac{\sqrt{N(SY^2) - (SY)^2}}{SY}$$

For Little Sandy - See Table 3.

$$C_v = \frac{\sqrt{30(159,077,700) - (65,170)^2}}{65,170}$$

$$= \frac{\sqrt{4,772,331,000 - 4,247,128,900}}{65,170}$$

$$= \frac{\sqrt{525,202,100}}{65,170}$$

$$= \frac{22,917}{65,170} = 0.35$$

C_v in percent $= 0.35 \times 100 = 35\%$

($C_v = 35\%$ differs from $C_v = 36\%$ in Table 3 because of differences in rounding numbers - 36% is used below)

Now enter charts on pages 21 and 22 with $C_v = 36\%$ and obtain ratios of Y to mean $Y(Y/\bar{y}) = Y/\bar{y}$ as follows, on the curves for N = 30

Recurrence Interval Yrs.	Recurrence Interval %	$Y/\bar{y}$	$Y = Y/\bar{y} \times \bar{y}$ * c.f.s.
2	50	.96 (Interpolated)	2,100
5	20	1.32	2,870
10	10	1.54	3,340
25	4	1.84	4,000
50	2	2.06	4,470

*$\bar{y}$ = mean Y = average rate of runoff

$$= \frac{SY}{N} = \frac{65,170}{30} = 2,173$$

The recurrence intervals, either in years or percent, and the Y values in c.f.s. may now be used to plot a frequency curve on logarithmic or probability paper, as shown in Figures 3 and 2, respectively.

by A. L. Sharp, SCS
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Table 1. Peak Annual Discharges of Little Sandy River and Johnson Creek, Oregon

Year	Little Sandy River	Year	Little Sandy River	Johnson Creek
1920	2,580	1935	2,480	
1921	2,500	1936	1,920	
1922	3,950	1937	1,370	
1923	3,680	1938	2,280	
1924	1,410	1939	1,610	
1925	1,820	1940	1,130	
1926	1,550	1941	1,860	578
1927	1,520	1942	1,160	937
1928	2,020	1943	3,050	1,770
1929	1,780	1944	1,000	260
1930	1,930	1945	1,720	529
1931	3,500	1946	2,940	888
1932	2,380	1947	3,040	1,420
1933	1,530	1948	2,460	1,900
1934	3,000	1949	2,000 *	2,090

* Estimated from torn recorder chart.

Table 2. Numbers of Occurrences of Hourly Rainfall by Classes Santa Ynez, California - 12-hour Storms.

Rainfall Class Inches in One Hour	(1) Number by Classes	(2) Number[1] Equaling or Exceeding Classes	(3) Number[2] Exceeding per Year (7 years of record)	(4) Number[3] per Year
.01 to .05	216	488	70	31
.06 to .10	106	272	39	15
.11 to .15	64	166	24	9
.16 to .20	37	102	15	5.3
.21 to .25	22	65	9	3.1
.26 to .30	15	43	6	2.1
.31 to .40	14	28	4	2.0
.41 to .50	10	14	2	1.4
.51 to .60	0	4	.6	0
.61 to .70	3	4	.6	.4
.71 to .80	0	1	.14	0
.81 to .90	1	1	.14	.14

1/ Column (2) obtained by summarizing column (1) from the bottom up.

2/ = Column (2) ÷ period of record (7 years)

3/ Column 1 ÷ period of record (7 years)

(DETERMINATION OF FREQUENCY OF RAINFALL AND RUNOFF)

Table 3. Peak Annual Discharges of Little Sandy River, Oregon and Recurrence Intervals, 1920-1949

Rank n	Rate of Flow	Recurrence Interval in Years and Percent of Occurrence									
				HAZEN				Gumbel** (Simplified)			
		N/n	$\frac{100\,n}{N}$	$N(n-\frac{1}{2})$	$\frac{100(n-\frac{1}{2})}{N}$	$\frac{N+1}{n}$	$\frac{100n}{N+1}$			Recurrence Intervals	
	c.f.s.	Yrs.	%	Yrs.	%	Yrs.	%	$(\text{cfs} \times 10^{-1})^2$	c.f.s	Yrs.	%
1	3,950	30	3.3	60	1.7	31	3.3	156,025	4,470	50	2
2	3,680	29	6.7	20	5.0	16	6.4	135,424	4,000	25	4
3	3,500	28	10	12	8	10	9.7	122,500	3,340	10	10
4	3,050	27	13	8.6	12	7.8	13	93,025	2,870	5	20
5	3,040	26	17	6.7	15	6.2	16	92,416	2,080	2	50
6	3,000	25	20	5.5	18	5.1	19	90,000			
7	2,940	24	23	4.6	22	4.3	23	86,436			
8	2,580	23	27	4.0	25	3.9	26	66,564			
9	2,500	22	30	3.5	28	3.4	29	62,500			
10	2,480	21	33	3.2	32	3.1	32	61,504			
11	2,460	20	37	2.9	35	2.8	35	60,516			
12	2,380	19	40	2.6	38	2.6	39	56,644			
13	2,280	18	43	2.4	42	2.4	42	51,984			
14	2,020	17	47	2.2	45	2.2	45	40,804			
15	2,000*	16	50	2.1	48	2.1	48	40,000			
16	1,930	15	53	1.9	52	1.9	52	37,249			
17	1,920	14	57	1.8	55	1.8	55	36,864			
18	1,860	13	60	1.7	58	1.7	58	34,596			
19	1,820	12	63	1.6	62	1.6	61	33,124			
20	1,780	11	67	1.5	65	1.5	64	31,684			
21	1,720	10	70	1.5	68	1.5	68	29,584			
22	1,610	9	73	1.4	72	1.4	71	25,921			
23	1,550	8	77	1.3	75	1.3	74	24,025			
24	1,530	7	80	1.3	78	1.3	77	23,409			
25	1,520	6	83	1.2	82	1.2	81	23,104			
26	1,410	5	87	1.2	85	1.2	84	19,881			
27	1,370	4	90	1.1	88	1.1	87	18,769			
28	1,160	3	93	1.1	92	1.1	90	13,456			
29	1,130	2	97	1.1	95	1.1	93	12,769			
30	1,000	1	100	1.0	98	1.0	97	10,000			

$N = 30$

Gumbel (Simplified) computations

Y = c.f.s. = rate of flow

$SY = 65,170$

$SY^2 = 159,077,700$

$(SY)^2/N = (65,170)^2/30 = 4,247,128,900/30 = 141,570,963$

$Sy^2 = SY^2 - (SY)^2/n = 159,077,700 - 141,570,963 = 17,506,737$

$\bar{Y}$ = Mean $Y = SY/N = 65,170/30 = 2,173$

s = standard deviation = $\sqrt{Sy2/(N-1)} = \sqrt{17,506,737/(30-1)}$

$= \sqrt{603,681} = 777$

C_v = coefficient of variation = $s/\bar{y} = 777/2,173 = .358$

$= 36\%$

* Estimated from torn chart

** See Potter's simplification